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PRECIPITATION HARVESTING FOR LIVESTOCK WATERING

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Final Report

Research Report

Precipitation Harvesting For Livestock Watering

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1. Introduction

A site at Termuende Farm, Western Beef Development Centre (WBDC) near Lanigan, was chosen by PFRA, PAMI, and WBDC for the site of the 10- and 30-steer capacity precipitation harvesting demonstration/research project.

Two separate but adjacent precipitation harvesting systems were designed, surveyed, excavated, and liners, aeration, pumping, and monitoring equipment were installed. Construction was started on May 26, 2004, and the system was complete and functional except for the lines to the livestock watering troughs prior to the end of June 2004 (**Figures 1** and **2**).

Figure 1. Large Collection/Storage System.

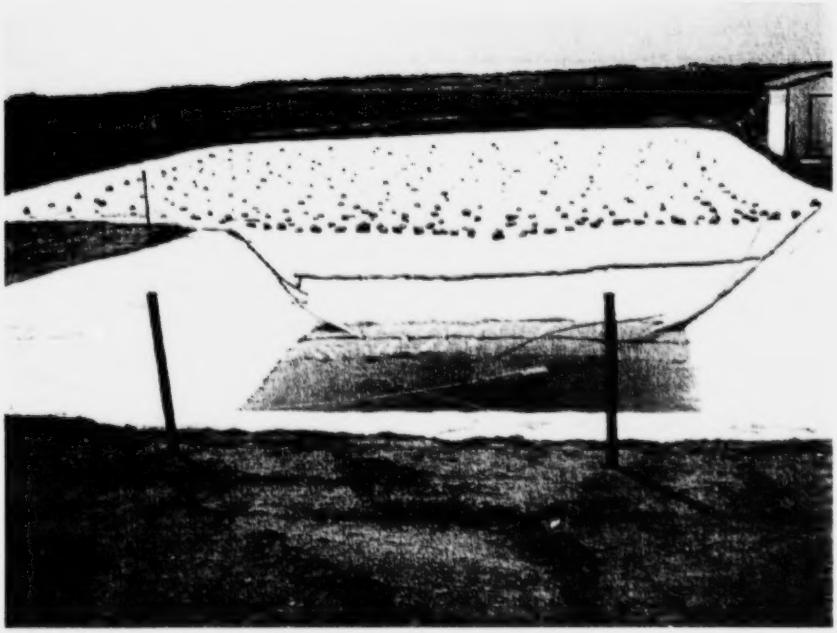


Figure 2. Small Collection/Storage System.

A large sign was installed at the site to describe the project and recognize the funding agencies.

Rainfall and cell water volume data was collected from June 16, 2004 to September 29, 2004. Collection efficiency (rain received vs. rain collected) for individual rainfall events over 10 mm was more than 81% with both collection systems. Overall collection and storage efficiency from June 16, 2004 to September 29, 2004, was about 54% for both systems.

Although there were problems with catchment liners, the first year of operation has shown the feasibility of precipitation harvesting.

In fall 2004, PFRA funded and arranged the installation of a snow catchment fence around the large storage cell.

In spring 2005, a solar powered water pressure system and waterlines were trenched in from each collection/storage system to livestock watering troughs. Flow meters were attached to each system to record water volumes.

Tours were conducted at the site with a total of 496 people attending.

2. Objectives

The project objectives are as follows:

1) To obtain a high quality source of water for up to 40 steers in a pasture area.

2) To obtain water reliably by gathering not only snow run-off but also rainwater into cells by way of a membrane covered drainage area.

3) To demonstrate the benefits of two construction methods for improved precipitation collection methods to the public.

3. Project Description

This project is managed and conducted by a team from PFRA and PAMI in cooperation with Western Beef Development Centre.

The precipitation harvesting site at Termuende Farm, WBDC, was selected, and surveying and excavation of the site started on May 26, 2004. The site consists of two separate collection/storage systems. The smaller system is designed to water 10 steers for 180 days and the larger system is designed to water 30 steers for 180 days.

The smaller system was designed based on a previous PFRA design. However, a bulkhead as used in a previous design was not needed, as tanks were not used to hold the water. As a result, all water from the collection area will be allowed to drain into the storage cell. The cell size was designed to collect water for 10 steers and has a catchment area and cell liner covered with a 20 mil proprietary polyolefin Enviro Liner material. The catchment area liner was secured by a large number of heavy rocks to prevent wind lift and damage to the liner. The yearly collection capacity is 238,800 L. The cell capacity will exceed yearly collection capability so an overflow system should not be needed. If higher than normal precipitation leads to excess water supply, it will be pumped out to prevent overflow.

The larger system, with a capacity of 714,000 L, was designed and constructed using identical principles but using a less costly construction grade UV resistant 6 mil polyethylene as a catchment area liner and a 20 mil Enviro Liner for the cell. The catchment area poly liner was secured by a large amount of rock in most of the drainage area to prevent lifting of the liner from wind. Berms at the liner edges were used in all cases to prevent drainage from outside of the lined areas.

The following calculations were based on PFRA sources and data. The requirements are:

- For 10 steers: 68.3 L/day x 180 days x 10 = 123,000 L
- For 30 steers: 68.3 L/day x 180 days x 30 = 369,000 L

The evaporation volume loss depends on the surface size of the storage cell. To allow for evaporation, a figure of 0.655 m of depth from the storage is used based on PFRA research. Evaporation from the 10-steer cell will amount to 115,800 L, so a total 10-steer retention requirement would be 123,000 L + 115,800 L = 238,800 L. This amounts to 238.8 m^3 of water.

Note that almost half the water requirement is for losses due to evaporation. Using tankage to store water eliminates this need but the high cost of tanks and problems with

algae make them impractical for large storage volumes. Perched artificial aquifers, another storage method, may be a cost effective solution.

The storage cells were sized to catch and hold one year's precipitation (at average precipitation levels) from an area adequate to water the 10 or 30 steers and allow for evaporation. This eliminated the need for an overflow capability, even if water is not used from the facility.

With average precipitation of 0.391 m, the precipitation area required for 10 steers is 610 m^2 (25 m x 25 m) and for 30 steers is 1,830 m^2 (42 m x 42 m). These calculations as shown below in **Table 1**, are for a full year's water supply and only 180 days usage.

Table 1. Approximate System Dimension.

Approximate System Dimension		
	10 Steer System	**30 Steer System**
Catchment area	610 m^2 (25 m x 25 m)	1,830 m^2 (42 m x 42 m)
Cell size	240 m^3 (approximately)	720 m^3
Top	14.3 m x 14 m	16 m x 30 m
Middle	7.9 m x 7.9 m	8.0 m x 23 m
Bottom	1.5 m x 1.5 m	3.5 m x 10 m
Depth	3.5 m	3.5 m
Volume	264 m^3	729 m^3
Liner required	155 m^2	465 m^2
Catchment area	671 m^2	2,000 m^2
Total Liner Required	**826 m^2**	**2,465 m^2**

Drawings of the proposed site are provided in **Appendix II**. The graphs in **Appendix I** illustrate that nearly 80% of rainfall occurs during April to September. The systems have been sized conservatively in that the cell surface area is not included in catchment calculations and cell depth is set at 3.5 m for ease of excavation. Actual dimensions may be slightly different due to on-site excavation errors or minor changes to facilitate liner placement.

Water measurements and control are being carried out by the following means:

- Rainfall will be measured with an electronically logged, battery operated, tipping bucket rain gauge. The storage cells will be precisely measured and computer models will be used to develop precise volume vs. water depth relationships. Precise depth level measurements and battery operated logging equipment will be installed in each storage cell (**Appendix III**). All systems are powered by two solar panels connected to battery storage. Water collection efficiency can then be calculated from volume and rainfall data.

- To allow for usage measurement, water from the cells will be pumped by a solar pump directly to a float valve in the stock tanks. Flow meters will be used between the pumps and water troughs to measure water use. Evaporation will be calculated as the difference between rainfall and usage.
- Water quality and collection efficiency from precipitation in both systems will be monitored over each summer.
- Both systems were fenced to prevent livestock damaging the liner systems. A "rodent wall" was constructed around the water catchment and cell area by using a wire mesh fence. The wire mesh, which is approximately 1 m wide, was placed on edge, half in the ground to discourage burrowing into the area. The storage cells were carefully surveyed when constructed to allow calculation of volume from water level measurement. Rainfall will be recorded continuously. Solar powered pumping systems will be used to pump the water to stock troughs outside the fenced area. Water usage from the storage cells will be calculated from volume vs. depth calculations and by flow meters. Aeration systems will be installed to enhance water quality.

Water quality, collection efficiency, and water use from precipitation in both systems will be monitored over the summer. Once the project is established and operating successfully, data will be generated and published to assist producers in all areas of the prairies to design an appropriate precipitation harvesting system for their geographic location. Precipitation harvesting areas and storage must be sized to suit local, total annual precipitation, peak precipitation events, usage, and evaporation rates.

The site will be used as a demonstration location to show producers an improved means of precipitation harvesting for livestock use. PAMI will prepare press releases to acquaint the press with the project and a PAMI Research Update will be printed and distributed at the end of the project. Information sheets will be printed for handing out at farms shows and at any other opportunities to communicate with producers. As well, PAMI will collaborate with PFRA to allow joint preparation of the most effective communication tools for technology transfer.

An annual project report and interim reports will be prepared by PAMI for use by PAMI for reporting to Agriculture Development Fund and CARDS and can be used by PFRA in developing technology transfer materials on the project.

4. Activities Performed to Date

4.1 2004 Activities

The site at Termuende Farm, WBDC, was selected, surveyed, and excavation of the site started on May 26, 2004. The collection areas had the sod removed and graded to a gentle slope leading to each storage cell. A backhoe was used to excavate both the small and large storage cells. Cell liner and catchment liners, were installed by PFRA and PAMI staff on June 9 and 10, 2004 (**Figure 3**). Heavy rocks were placed on the catchment area to prevent the wind from lifting and damaging the liners. A rodent fence consisting of stiff 1.2 m high mesh, trenched 75 cm into the ground and 45 cm above ground was installed around both systems to exclude rodents (mostly gophers) and prevent damage to the catchment and cell liners.

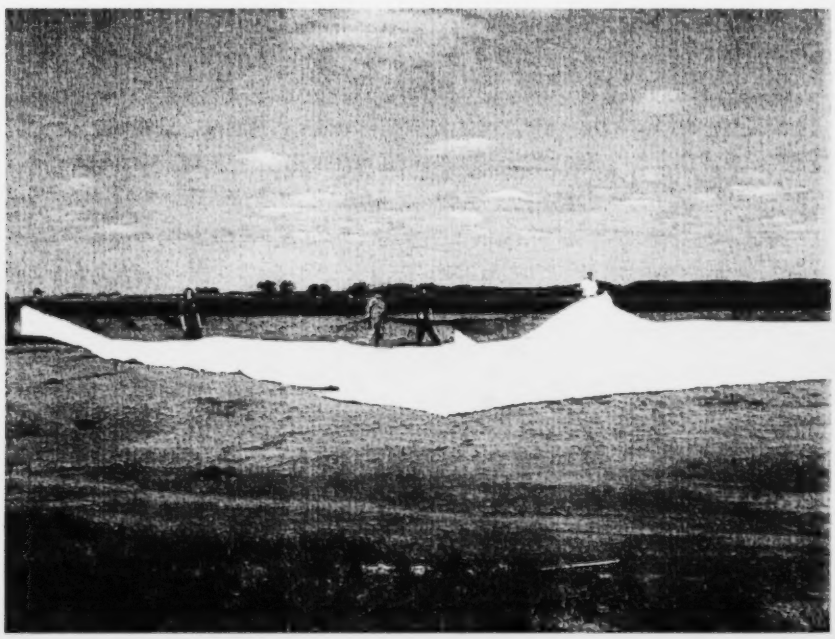


Figure 3. Installing Cell Liner.

A small shed was positioned between the two storage cells to contain equipment supplied and installed by PFRA including storage batteries, aeration equipment, water pressure systems, water depth transducers, and data logging equipment. Two solar panels were installed close to the shed to provide power for the systems and data logger.

Following installation of the catchment liners, it was discovered that there were not enough rocks to adequately hold down the liners, especially in the large catchment area.

This resulted in lifting of the liner and tearing of part of the liner in the large catchment area (**Figures 4** and **5**).

Figure 4. Lifting of Liner.

Figure 5. Tearing of Liner.

The liner was repaired and additional heavy rocks added to prevent further problems with the liner (**Figure 6**).

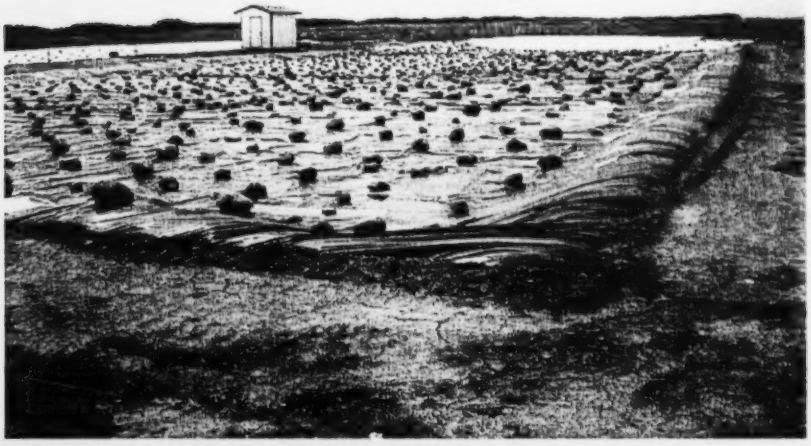


Figure 6. Repaired Liner with Additional Rocks.

A large sign was installed at the site to describe the project and recognize the funding agencies (**Figure 7**).

Figure 7. Sign Describing the Project.

Tours were the main method of communicating the benefits of the system to the public. Following is a list of tours conducted at the site during the summer/fall of 2004:

- Western Beef Development Centre, field day – 100 people
- Saskatchewan Watershed Authority – 25 people
- 4th Year Animal Science Class – 40 people
- Drop-in local visits – 10 people
- 2nd Year Agriculture Class – 10 people
- PFRA Management tour – 90 people

A total of 275 people have toured the site by October 2004.

In addition, a number of local residents and visitors have self-toured the site.

Interviews were given to CFQC television and the Western Producer about the project. The television interview was broadcast on CTV's prairie network and a newspaper article was published in the Western Producer.

In late fall 2004, snow catchment fencing was constructed around part of the large system for snow trapping (**Figure 8**).

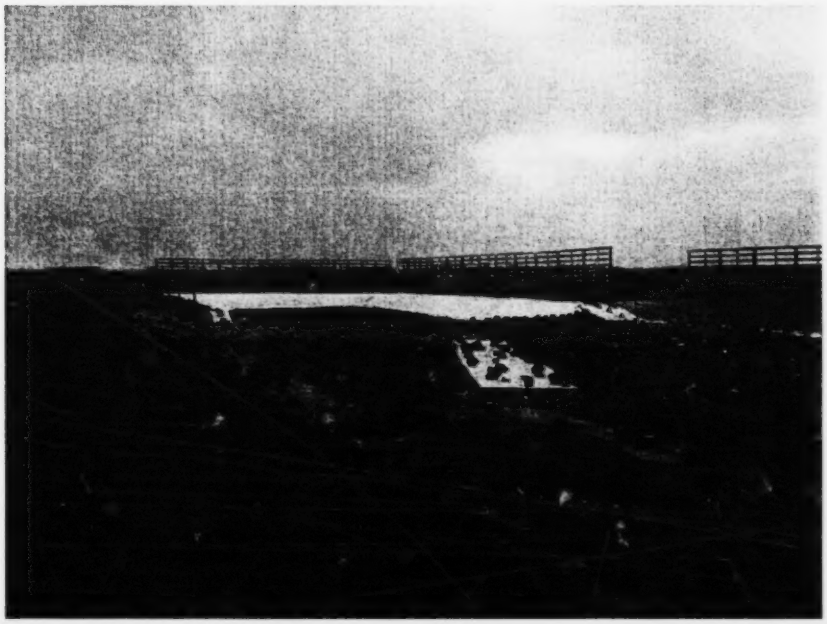


Figure 8. Fencing Installed for Snow Trapping.

Prior to winter both storage cells were partially pumped out and instrumentation removed.

4.2 2005 Activities

Over the winter of 2004 – 2005, major damage again occurred to the 6 mil poly in the large catchment area (**Figure 9**).

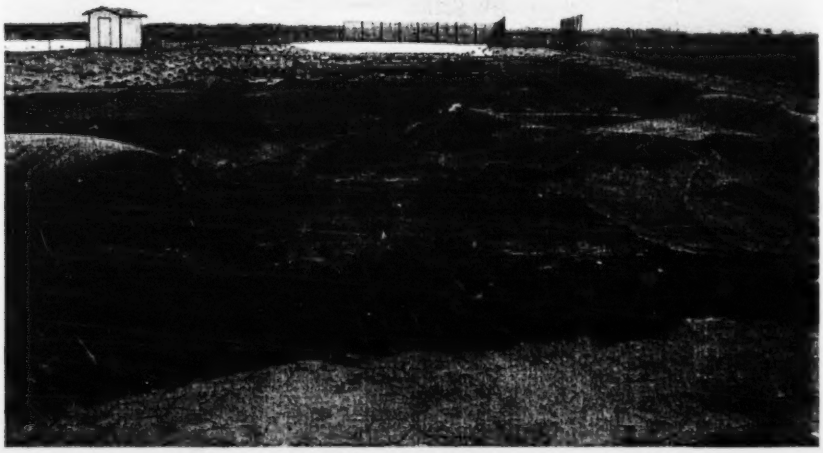


Figure 9. Damage to the Large Catchment Liner.

As the liner damage was extensive, a 15 x 30 m (50 x 100 ft) area of the liner was replaced with new 6 mil poly, and additional stones added to reduce further damage. Less serious catchment liner damage occurred in July and was repaired in August.

In spring 2005, solar powered water pressure systems and water lines were trenched in from each collection/storage system to livestock watering troughs. Flow meters were attached to each system and the water volumes recorded using the data log.

Rainfall and other data were again collected in 2005 for analysis during the winter.

Tours were again the main method of communicating the benefits of the system to the public. Following is a list of tours conducted at the site during the summer/fall of 2005:

- Western Beef Development Centre, field day – 150 people
- Greenhouse Gas field day – 25 people

- Chinese delegation/U of S – 20 people
- Drop-in local visits – 13 people
- WBDC seminar – 6 people
- U of S tour – 5 people
- Scott Wright – 1 person
- Mongolian Ag Minister – 1 person

A total of 221 people toured the site in summer 2005.

An interview was given to CFQC television. The interview was broadcast on CTV's prairie network.

Interviews with reporters have led to articles in the Western Producer and Cattleman magazine.

5. Project Objectives That Have Been Met

The objective to obtain a high quality source of water for 40 steers has been met, as the system is now fully functional.

The objective to obtain water reliably by gathering snow run-off and rain water into cells by way of a membrane covered drainage area, has been met as the collection/storage cell systems are functional and efficiently collecting precipitation.

The objective to demonstrate the benefits of two construction methods for improved precipitation collection methods to the public is on-going. The demonstration process is ongoing with tours of the site in 2004 and 2005.

6. Personnel

6.1 PAMI Manpower Supplied

It is PAMI's policy not to release individual salary information. The charge rates shown are the average salaries and benefits for each category of employee and are as shown in the ADF application. The benefit and overhead costs associated with salaries are partially to the PAMI applicant contribution and part of overhead is applied to other project costs.

8. Equipment

PAMI has not purchased any equipment for the project. PFRA has purchased solar panels, pumps, data logger, flow meters, tipping bucket rain gauge, etc.

9. Obstacles/Successes

The main obstacle encountered was the problem of lifting and/or tearing of the collection area liner. The problem has been partly solved with tape repairs to the tears and additional heavy stones to hold the membrane in place. As the lifting/tearing problem recurred in fall/winter of 2004, in 2005 an improved method of ballasting the liner needs to be investigated. In order to maintain reliable data collection from year to year in this project, only minor changes can be made. The system needed to hold the poly membrane in place will be researched in a new project.

The second obstacle was the problem with the accuracy of data collection and/or data storage in summer 2005. Holding cell depth measurement and water volume pumped to stock troughs was inaccurately measured or recorded in 2005, resulting in less accurate data compared to 2004.

Successes include the excellent cooperation among PFRA, Termuende Farm, and PAMI staff to get the project underway and functioning. The system has now been in operation for full two years and high quality water has been efficiently collected and distributed from both storage cells.

10. Timelines/Budget

All construction and equipment installation (except for minor details), water delivery, the cattle fence and snow fence are complete at the time of this report. Project costs to date are close to budget except for liner costs and labour. Those costs are over budget. Labour costs are higher than expected due to the extra labour required to repair the torn collection membrane and adding extra rocks to both collection systems.

11. Results and Discussion

The two precipitation harvesting systems were completed and collected high quality water in spring/summer of 2004 and 2005.

Lifting and tearing of part of the large catchment area liner occurred soon after construction. Late in the year and over winter further damage occurred to the liner in the large collection area. The 6-mil poly lifted and moved the stones into piles at the NE part of the collection area. Further liner repairs and extra stones will be required to fix the problems.

11.1 Efficiency of Rainfall Collection 2004

Both systems were electronically monitored from June 16, 2004 to September 29, 2004. Data gathered included precipitation and the depth of water in each storage cell. PFRA developed computer models to accurately determine water volume vs. cell depth.

During the test period, there were four rain events resulting in accumulated precipitation of more than 10 mm. These events provided 98.7 mm or 71% of the 138.8 mm rainfall received in the monitoring period.

Rainfall collection efficiency refers to the percent rainfall collected in the storage cells compared to the total amount of rain received in the combined surface area of the collection area and storage cell.

On July 21, 2004, 13.3 mm of precipitation accumulated at the site resulting in 26,250 L of water collected in the large storage cell for a collection efficiency of 81.7% (**Figure 10**).

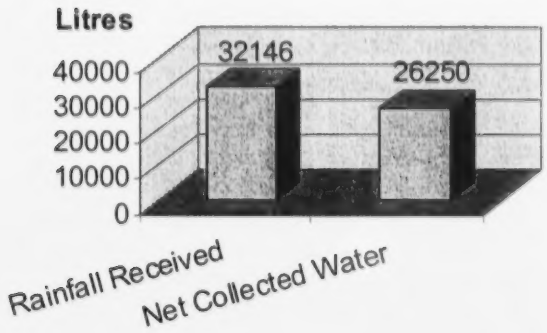


Figure 10. Collection Efficiency of the Large System from 13.3 mm Rain on July 21, 2004.

At the small system, 10,037 L of water collected in the storage cell for a collection efficiency of 82.7% (**Figure 11**).

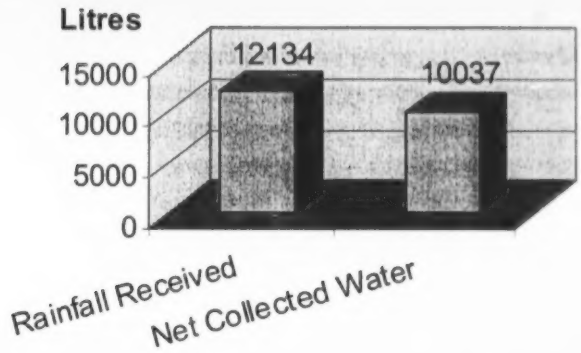


Figure 11. Collection Efficiency of the Small System from 13.3 mm Rain on July 21, 2004.

On August 7 and 8, 2004, 25.5 mm of rain accumulated at the site. At the large system, 26,250 L of water collected in the storage cell for a collection efficiency of 81.6% (**Figure 12**).

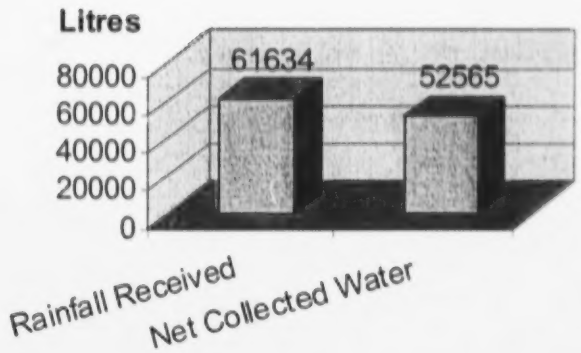


Figure 12. Collection Efficiency of the Large System for a 25.5 mm Rain on August 7 and 8, 2004.

At the small system, 19,078 L of water collected in the storage cell for a collection efficiency of 82.0% (**Figure 13**).

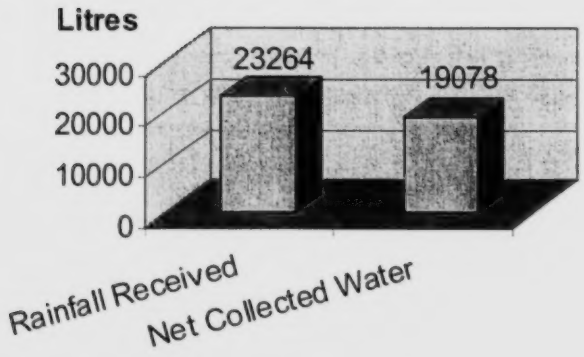


Figure 13. Collection Efficiency of the Small System for a 25.5 mm Rain on August 7 and 8, 2004.

On August 22 and 23, 2004, 45.7 mm of rain accumulated at the site. At the large system, 92,047 L of water collected in the storage cell for a collection efficiency of 83.3% (**Figure 14**).

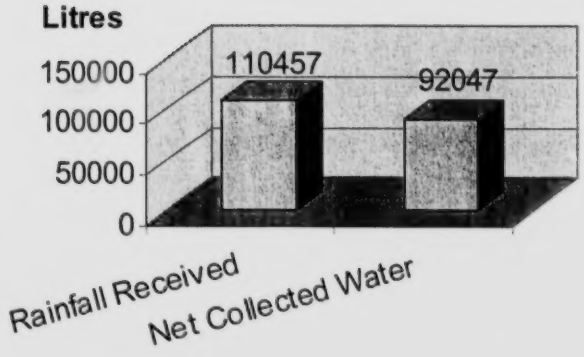


Figure 14. Collection Efficiency of the Large System for a 45.7 mm Rain on August 22 and 23, 2004.

At the small system, 39,070 L of water collected in the storage cell for a collection efficiency of 93.7% (**Figure 15**).

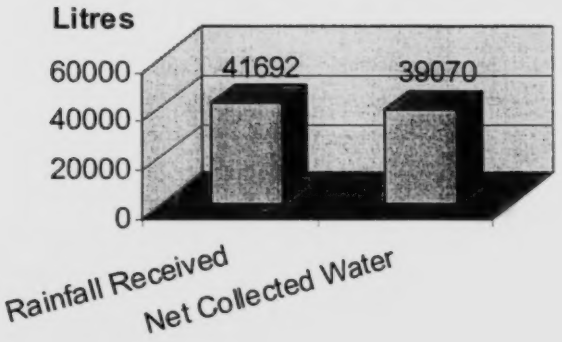


Figure 15. Collection Efficiency of the Small System for a 45.7 mm Rain on August 22 and 23, 2004.

Overall, the collection efficiency for individual rainfall events over 10 mm was very good with more than 81% of total rainfall collected in the storage cells.

11.2 Overall Collection and Storage Efficiency 2004

Overall efficiency refers to the net amount of rainfall collected and saved in the system compared to the total amount of rainfall received on the surface area of the collection and storage systems during the test season.

The net amount of rainfall collected June 16, 2004 to September 29, 2004, for the large system was 181,918 L for a collection and storage efficiency of 54.2% (**Figure 16**).

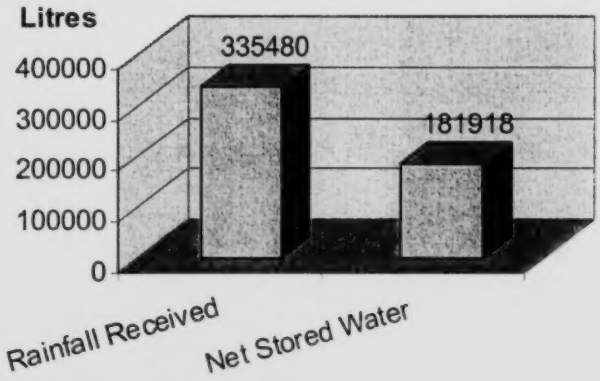


Figure 16. Collection and Storage Efficiency of the Large Precipitation Harvesting System in the Summer of 2004.

The net amount of rainfall collected June 16, 2004 to September 29, 2004 in the small system was 69,114 L for an overall collection and storage efficiency of 54.6% (**Figure 17**).

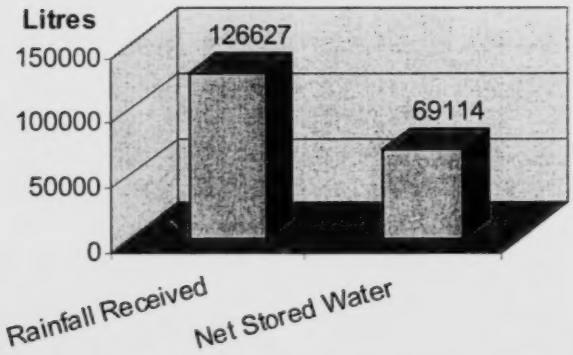


Figure 17. Collection and Storage Efficiency of the Small Precipitation Harvesting System in the Summer of 2004.

The more than 25% reduction in collection and storage efficiency compared to the collection efficiency of single rainfall events is due to evaporation from the collection area and from the surface of the storage cells resulting in the 25% reduction in efficiency. Lower collection efficiency in some rainfall events on the large cell may be due to tears in the poly that had not been repaired at the time of rainfall.

11.3 Livestock Water Volume Requirements

The system was designed to provide quality water for 10 steers on the small system and 30 steers on the large system. As the system was monitored for 106 days in the summer of 2004 and the daily livestock water requirement was 68.3 L/head/day, the small system met 95.5% of water requirements and the large system met 83.8% of the requirements.

11.4 Efficiency of Rainfall Collection 2005

Both systems were monitored from May 9, 2005 to October 2, 2005. Data gathered included precipitation, depth of water in each storage cell and water volumes delivered from each cell to remote livestock watering troughs. PFRA developed computer models to accurately determine storage cell water volume from cell depth.

Spring and summer 2005 was very wet at the test site, with a total of 306 mm of precipitation recorded from May 9, 2005 to October 2, 2005.

During the test period, there were nine rain events, resulting in accumulated precipitation of 10 mm or more. These rainfall events provided 223 mm or 73% of the total rainfall received in the monitoring period.

Rainfall efficiency refers to the percent rainfall collected in the storage cells (adjusted for pump out to livestock troughs) compared to the total amount of rain received in the combined surface area of the collection area and storage cell.

Analysis of the data from the precipitation event 2005 season showed highly erratic collection efficiency (**Tables 2 & 3**).

Table 2. Small System Collection Efficiency from Selective Rainfall Events 2005.

Date	Precip (mm)	Rainfall Received (L)	Rainfall Collected (L)	Pumped Out (L)	Net Collected (L)	Collection Efficiency (%)
May 16 - 17	24.9	21,806	24,239	34	24,273	111.3
May 20	27.0	23,629	25,958	9	25,967	109.9
June 1	9.9	8,664	6,822	28	6,850	79.1
June 16 – 17	19.1	16,716	15,250	0	15,250	91.2
July 1 – 3	19.7	17,241	9,814	252	10,066	58.4
August 22 – 23	32.9	28,793	22,881	0	22,881	79.5
August 29 – 30	47.1	41,220	25,597	0	25,597	62.1
September 4	15.1	13,215	12,848	0	12,848	97.2
September 9	26.8	23,454	18,274	1,081	19,355	82.5

Table 3. Large System Collection Efficiency from Selective Rainfall Events 2005.

Date	Precip (mm)	Rainfall Received (L)	Rainfall Collected (L)	Pumped Out (L)	Net Collected (L)	Collection Efficiency (%)
May 16 - 17	24.9	58,535	41,403	34	41,437	70.8
May 20	27.0	63,472	49,119	9	49,128	77.4
June 1	9.9	23,273	15,192	28	15,220	65.4
June 16 – 17	19.1	44,900	29,914	0	29,914	66.6
July 1 – 3	19.7	46,311	16,414	252	16,666	36.0
August 22 – 23	32.9	77,341	54,835	0	54,835	70.9
August 29 – 30	47.1	110,723	85,519	0	85,519	77.2
September 4	15.1	35,497	26,546	0	26,546	74.8
September 9	26.8	63,001	46,213	1,081	47,294	75.1

Efficiency of collection of individual rainfall events ranged from 36% to 77% in the large system and 58% to 110% in the small system. As the data from summer 2004 was much more consistent compared to 2005, further investigation and data analysis was completed in an attempt to explain the wide range of results. Variables that could affect the results include:

- Inaccurate precipitation measurement
- Inaccurate storage cell depth measurement and/or conversion to litres.
- Inaccurate measurement of water volumes pumped to stock troughs.
- Inaccurate data collection from the data logger.

Precipitation measurement at the site was compared to manual and automated precipitation measurements at nearby sites on the farm. Comparison of this data indicated that the precipitation data from the precipitation harvest site was similar to nearby readings except for one 21.4 mm precipitation event on July 29. On this date, no precipitation was recorded at the other sites and there was no change in the depth (volume) of either storage cell. As a result, this data was removed from the analysis.

With respect to the amount of water held in storage cells, the depth of water in the cells may have affected the accuracy of the conversion of pressure (depth) to water volume. As the cells are shaped somewhat like an inverted bell, changes in pressure (depth) in the bottom half of the cell have a much smaller effect on water volume compared to similar changes in pressure (depth) when the holding cells are closer to capacity. As the water volumes in both cells were much higher in 2005 compared to 2004, this might explain the larger differences in collection efficiency. In future years the cells will be pumped out in spring to improve measurement efficiency.

The third factor, inaccurate measurement of water volumes pumped to stock troughs. As the main operational difference between 2004 and 2005 was the addition of metered water delivery systems to livestock troughs, it is likely there was a problem with either metering accuracy or logging of the data. This is confirmed by a large reduction in seasonal efficiency between 2004 and 2005. As 2005 was much wetter compared to 2004, it is logical that the missing water was pumped to the troughs without accurate measurement or recording.

11.5 Overall Collection and Storage Efficiency 2005

Overall efficiency refers to the net amount of rainfall collected and saved in the system compared to the total amount of rainfall received on the surface area of the collection and storage systems during the test season.

The net amount of precipitation collected from May 9, 2005 to October 2, 2005 in the large system was 146,359 L for a collection and storage efficiency of 20% (**Figure 18**).

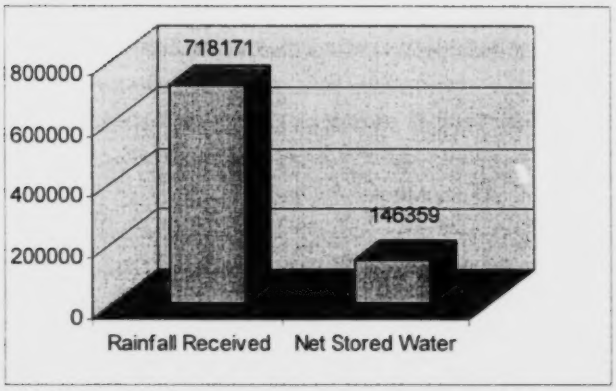


Figure 18. Collection and Storage Efficiency of the Large Precipitation Harvesting System in the Summer of 2005.

The net amount of precipitation collected from May 9, 2005 to October 2, 2005 in the small system was 42,785 L for a collection and storage efficiency of 16% (**Figure 19**).

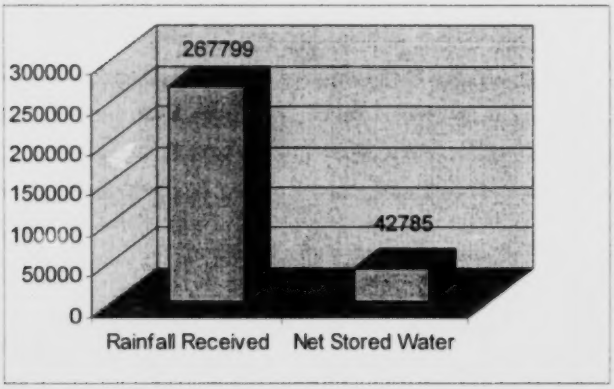


Figure 19. Collection and Storage Efficiency of the Small Precipitation Harvesting System in the Summer of 2005.

As the overall collection storage efficiency was over 50% for both systems in 2004 and 2005 was a wetter year, it is illogical that the seasonal precipitation was less than half of the previous year. The most logical explanation for the discrepancy is incorrect measurement of pump out to the livestock troughs. This measurement error will be investigated and corrected in future years.

11.6 Excavation and Liner Costs

Small system excavation and liner costs, excluding installation labour, were \$0.63/ft^2 of surface area for a total cost of \$6,115 (**Appendix VI**).

Large system excavation and liner costs, excluding installation labour, were \$0.34/ft^2 of surface area for a total cost of \$8,804 (**Appendix VII**).

The main reason for the lower cost/unit of the large system was due to the substitution of 6 mil black poly in place of the more expensive Enviro Liner in the collection area. However, the 6 mil poly was more susceptible to wind damage and unless an economical solution is found to prevent the lifting and tearing problem, the 6 mil poly may not be a practical choice.

12. Conclusions

The demonstration has been a combination of major success and setbacks. The success of the project has been to design, construct, monitor, operate, and demonstrate two collection/storage systems.

Collection efficiency with both systems was very good in 2004, with more than 81% of rainfall collected in storage cells from precipitation events exceeding 10 mm. Overall collection/storage efficiency including losses from small rain event evaporation from the collection surfaces and storage cell evaporation was about 54%. The net amount of water collected in the small and large storage cells provided 95% and 83.3% of the water needs of 10 and 30 steers, respectively.

Collection efficiency measurements from individual rainfall events were variable in 2005, likely due to inexact depth (volume) measurements in both storage cells. Seasonal efficiency measured in 2005 was much lower compared to 2004 due to inaccurate measurement of outflow to livestock troughs. While the first year's measurement of efficiency shows how well the system works, the 2005 data demonstrated it can be difficult to accurately measure and record water levels and rainfall.

The setbacks in both years are technical problems with the collection area liners and measurement problems in year two. Liner lift in the small collection area was solved with the addition of heavy rocks. In contrast, there were ongoing problems with the liner in the large collection area. The problem with liner lift and tearing in the west half of the collection area was fixed with tape repair and additional heavy stones. However, further lifting and tearing problems occurred with the 6 mil poly liner in the west part of the collection area that was not solved with tape repairs and extra stones. Further repairs and additional stones were required to bring the liner back into operating condition. High labour cost and the inefficiency of using rocks to secure the collection liner means that a more efficient method of ballasting the liner needs to be found.

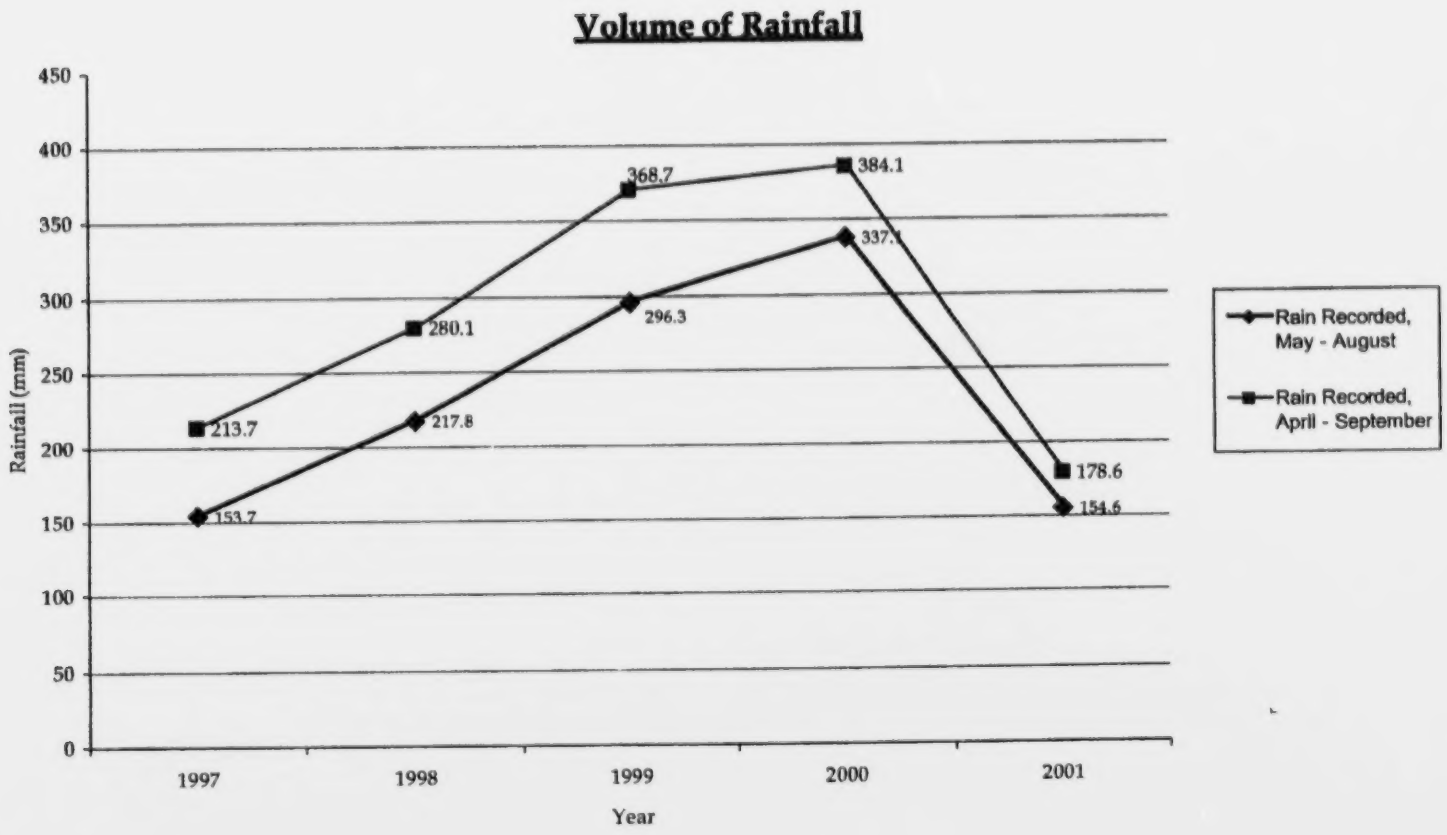
Overall, the project has shown the feasibility of precipitation harvesting. Fine-tuning will be needed to move the demonstration to practical application.

13. ICAR Data Entry

The associated ICAR number for this project is #33331553.

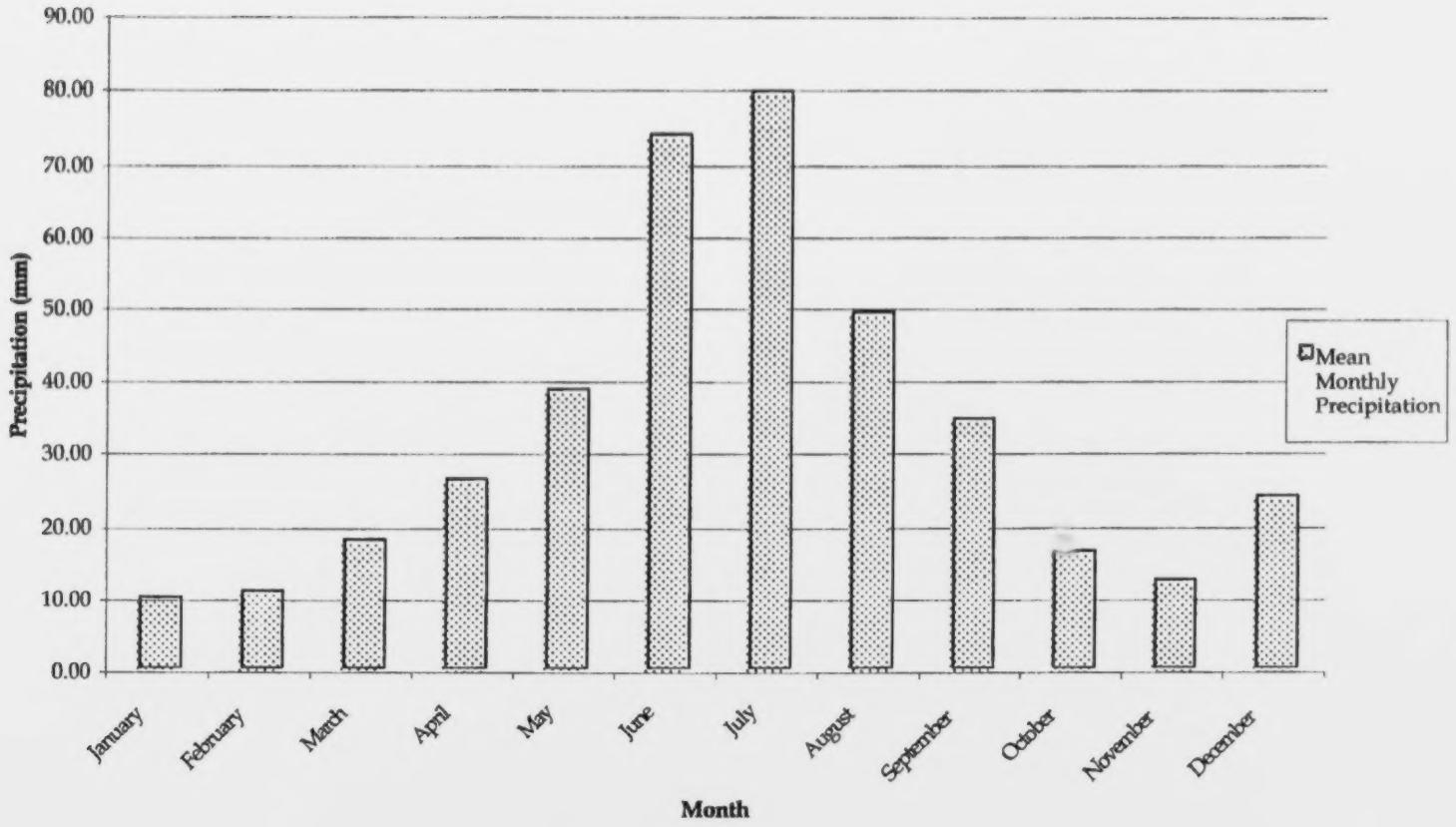
Appendix I

Graphs

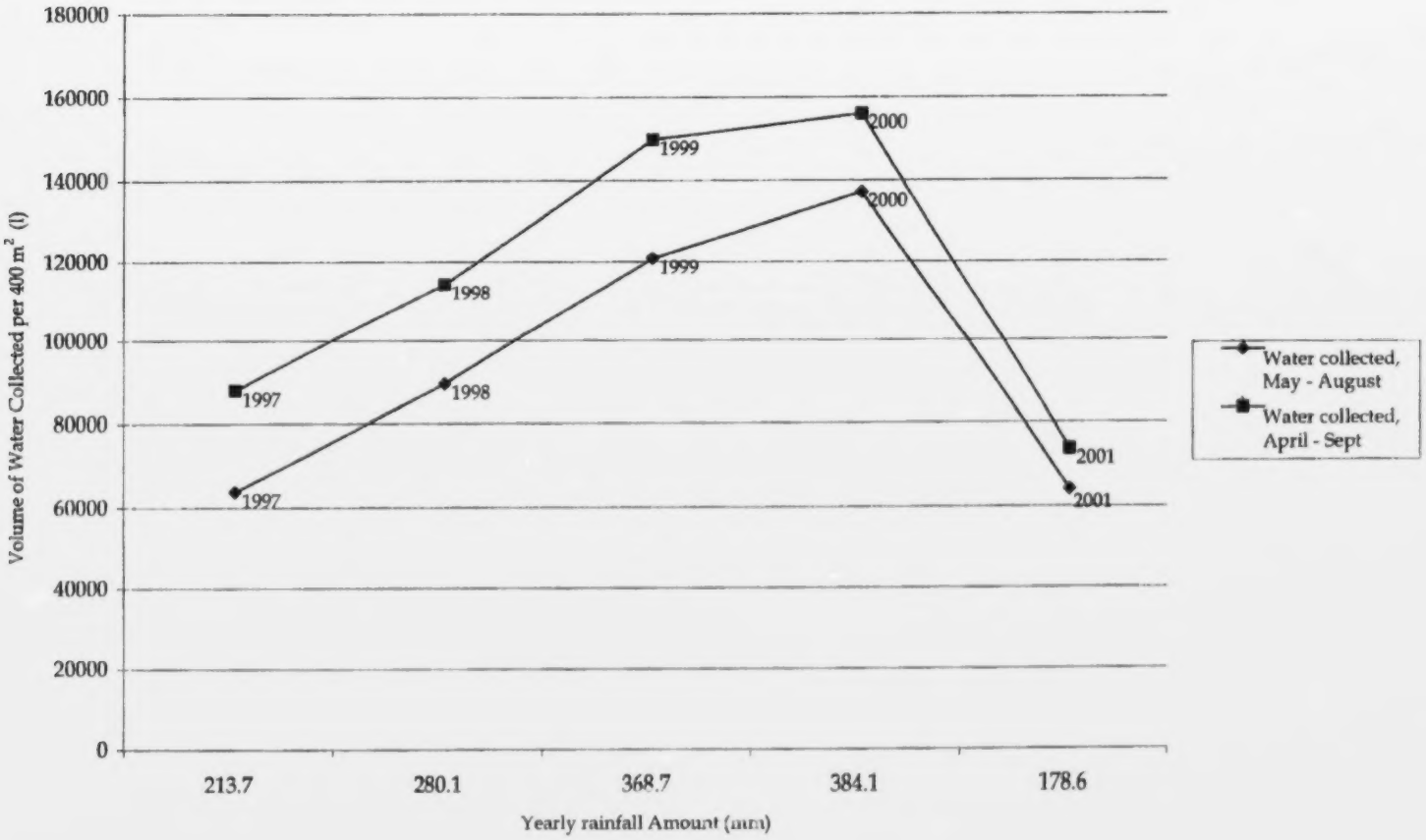

Volume of Rainfall
450
400
350
300
250
200
150
100
50
0
Rainfall (mm)
213.7
280.1
368.7
384.1
178.6
153.7
217.8
296.3
337.1
154.6
1997
1998
1999
2000
2001
Year
Rain Recorded, May - August
Rain Recorded, April - September

Graph 3

90 year Mean Precipitation at Watrous vs. Month

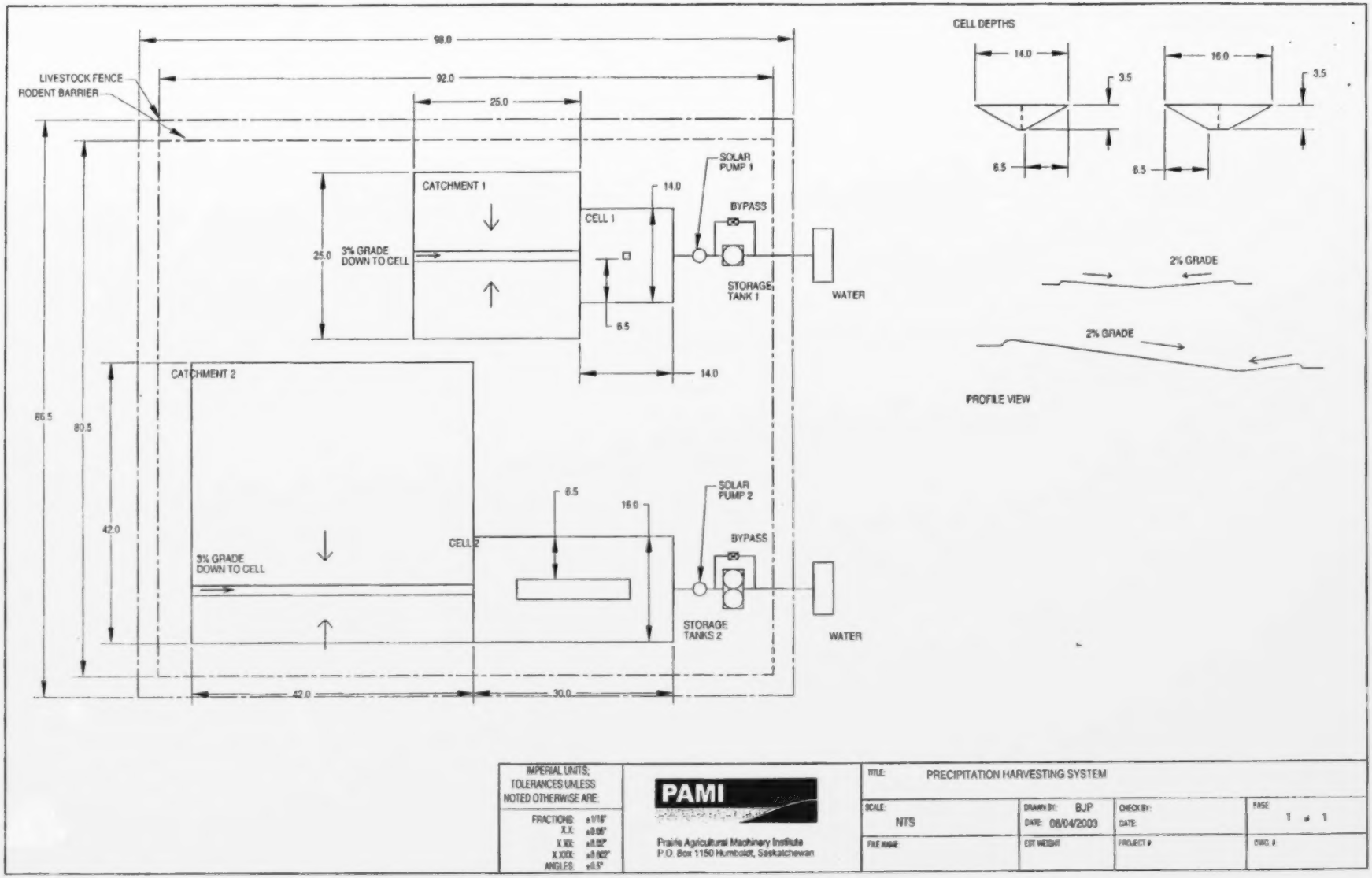


Volume of Rainwater Collected



Appendix II

Drawings



IMPERIAL UNITS; TOLERANCES UNLESS NOTED OTHERWISE ARE: FRACTIONS: ±1/16" X.X: ±0.05" X.XX: ±0.02" X.XXX: ±0.002" ANGLES: ±0.5°	PAMI Prairie Agricultural Machinery Institute P.O. Box 1150 Humboldt, Saskatchewan	TITLE: PRECIPITATION HARVESTING SYSTEM	
		SCALE: NTS	DRAWN BY: BJP DATE: 08/04/2003 CHECK BY: DATE: PAGE 1 of 1
		FILE NAME:	EST WEIGHT: PROJECT #: DWG. #

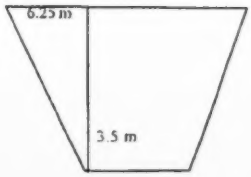
Cell and Catchment Area Calculations

Cell Volume

Top 14.3 m x 14.0 m = 200.2
Middle 7.9 m x 7.9 m x4 = 249.64
Bottom 1.5 m x 1.5 m = 2.25
Depth 3.5m
3.5 m x 451.9 ÷ 6 = 263.7 m^3

Cell Surface Area

Side 1



A = W x L
3.5 m x 1.5 m = 5.25 m^2

A = ½ B x H
½ (6.25 x 3.5) = 10.9 m^2

21.8 + 5.25 = **27.1** m^2

Area = 27.1 m^2 x 2
= **54.2** m^2

Side 2

A = W x L
= 5.25 m^2

A = ½ B x H
½ (6.4 x 3.5) = 11.2 m^2

Area = 27.7 m^2 x 2
= **55.4** m^2

Bottom

A = W x L
1.5 m x 1.5 m = **2.25** m^2

Surface Area: 111.9 m^2

Allow 0.5 m on each side for securing the liner to the ground. Also 10% of total volume must be added to allow for seams and over lap.

Bringing total area to: 11.9 m^2 + 28.3m^2 + 111.9m^2 = **155 m^2**

Total Surface Area: 155 m^2

Appendix III

Instrumentation

Call (800) 876-1172
US & Canada

Phone (916) 638-3429
7:30 AM to 4 PM PST
FAX (916) 638-3270
globalw@globalw.com

Global Water
Instrumentation, Inc.

Complete Catalog

Level Logger

Level Sensor

Flow Probe

Stormwater Samplers

Wastewater Samplers

Rentals

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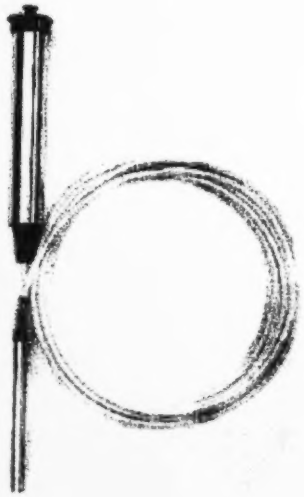
Organizations and Links

Page Last Updated
March 19, 2003

Water Level Logger (WL15)

Pressure transducer and datalogger combination



- Easy to operate and install
- Palm Pilot software simplifies data collection
- Exports data directly to spreadsheets for analysis
- No need to remove sensor for data collection or battery change

- Highly accurate water level measurements
- Multiple ranges available from 3' to 250'
- User programmable date, recording interval, site name
- Real-time readout of current data
- Unique 0-3' range for shallow water
- Wet-wet transducer eliminates vent tube concerns
- Automatic barometric pressure and temperature compensation

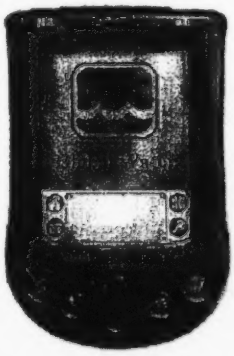
- Highly accurate water level data in the palm of your hand

Download PDF Files:
WL15 Manual
WL15 Quick Reference
WL15 Brochure

Downloading the manual may take several minutes depending on your connection speed.
To view the manual your computer must have Adobe® Acrobat® Reader™ Version 4.0 or later.

Scroll to:
Product Description
Specifications
Software Information
Installation
Applications
Options and Prices

Palm Pilot Software available
Call or email for more information.



Description

The Water Level Logger, WL15 provides a datalogger with a submersible pressure transducer for remote monitoring and recording of well depth measurements and water pressure data. Use the water depth data from the water level recorder and a water velocity meter to measure flow in streams and rivers. This highly reliable and accurate water logger records 24,400 readings and is programmable from one reading per second to one reading per day. Ranges of 0-3', 0-15', 0-30', 0-60', 0-120' and 0-250' are available. A 25' cable is standard, and optional cable lengths are available up to 500' (WLEXC).

The water level recorder houses its data logger in a weather-resistant cylindrical enclosure that slips inside a 2-inch pipe. The data recorder is easily adapted with standard hardware for well head mounting or other installations. The internal 9 VDC battery powers the water level meter and level sensor for one year. The water level monitor converts the 4-20mA water depth reading to a digital value and storing the water measurement in the level-logger's memory. All Global Water Level Loggers include data logging software for Windows-based PC's, allowing easy upload of recorded data to standard spreadsheet programs on a PC computer.

Global Water's Water Level Sensors are fully encapsulated with marine-grade epoxy. The submersible pressure transducer's electronics are encased in marine grade epoxy so that moisture can never leak in or work its way down the vent tube to cause drift or level sensor failure (as is the case with other pressure sensors). The vent tube is sealed directly to the sensing element, and any moisture that may enter the vent tube only comes in contact with a silicon sensing device, not the electronics.

Global's submersible pressure transducers use a unique silicon diaphragm to interface between the water and the sensing element. This silicon diaphragm is highly flexible and touches the sensing element, producing a sensor with exceptional linearity and very low hysteresis. Metal foil diaphragms tend to crinkle and stretch out over time causing drift, linearity, and hysteresis problems. The design of Global Water's Water Level Sensor eliminates these problems. The water sensor also utilizes a stainless steel micro-screen cap to protect the sensing element. This protective cap has hundreds of openings, making fouling the sensor with silt, mud or sludge virtually impossible.

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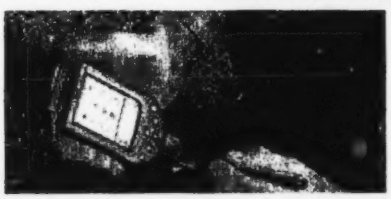

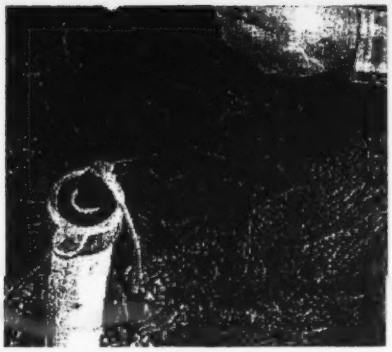

Specifications

Submersible Pressure Transducer

Sensor Element: Silicone Diaphragm, Wet/Wet Transducer
Pressure Range: 0-3', 0-15', 0-30', 0-60', 0-120', 0-250'
Linearity and Hysteresis: ±0.1% FS
Overpressure: 2 x full scale range
Burst Pressure: 10 x full scale range
Accuracy: ±0.1% of full scale at constant temperature, ±0.2% over 35°F to 70°F range
Compensation: Uses dynamic temperature compensation 30-70 F. Automatic barometric pressure compensation

Housing

Material: 304L Stainless Steel, SS microscreen (hundreds of holes to prevent fouling), electronics are fully encapsulated in marine grade epoxy, guaranteed not to leak
Size: up to 7" long x 3/4" diameter (small enough for a 1" well)

WL15 Cable

Conductors: 4 each 22 AWG
Jacket Material: 87A shore hardness Polyethylene
Vent Tube Material: HD Polyethylene
Shield: Aluminum Mylar
Outer Diameter: 3/16"
Temperature Range: -22° to +185°F
Weight: 0.7 oz/ft*Length:* Standard 25' (up to 500')

WL15 Water Level Data Logger

Memory: Non-volatile flash memory
Battery Life: Up to 3 years (depending on recording intervals)
Resolution: 12 bit
Moisture Protection: Acrylic coat (prevents damage to electronics from condensation)
Storage Capacity: 24,4000 time and date stamped data points
Recording Rate: Linear fixed intervals from 1 per second to once every 32,000 seconds (also 0-32,000 minutes, hours, and days); Logarithmic test (for pump and slug tests)
Data Overwrite: Select memory wrap or unwrap (unwrap will stop logging data once memory is full)
Clock: Synchronizes to the time and date of user's computer
Enclosure: 1 7/8" diameter x 12" length (fits inside a 2" well), stainless steel UV protected PVC vented for barometric pressure compensation
Weight: 1.6 lbs (with battery and 25' cable)
Communication: RS232 (cable provided)
File Type: Comma Separated Value (.CSV)

Global Water Software

Compatible with Microsoft's Windows 95, 98, ME, 2000, NT, and XP
Windows and Excel are trademarks of the Microsoft Corporation.
Tabular Display/Printout
Data in standard spreadsheet format
RS232 cable included (connects logger's data port to PC)

↑ Top of Page

Software

The Water Level Logger includes Global Water Software, Windows-based software that provies many useful features, such as real time monitoring, measurement interval and engineering unit selections, station ID, and sensor calibration. The Global Water Software makes accessing stored data and setting options easy. Data downloaded from the Water Level Logger can easily be opened in any PC spreadsheet program for analysis and graphic presentation.

The Global Water Software will run on a PC-type laptop or desktop computer running Windows 95 or later. The Water Level Logger requires a computer that is equipped with a standard RS232 serial

communication port. The Water Level Logger includes a RS2.. cable (for communication between the logger and your computer).

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Installation and Applications

The Water Level Logger's pressure sensor may be placed slightly below the lowest expected water level. When ordering, select the sensor range that will cover the maximum water level change (this is not necessarily the total depth of water). Select the smallest water level range possible to ensure greatest accuracy.

The Water Level Logger has a cylindrical enclosure that is designed to slide into a 2-inch PVC pipe. For monitoring groundwater, the sensor can be installed in a PVC pipe with its lip resting on the well's edge. For monitoring surface water, a protective stilling well can be constructed of PVC pipe with several holes near the bottom to allow water to flow through the pipe and reach the sensor. The pipe may be attached vertically to a post, or on a slant down the bank.

For other Water Level Logger installation tips, click HERE.

Groundwater Installation

Surface Water Installation

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Applications

Flood Analyses, Hydrant Pressure, Irrigation Canals, Groundwater Monitoring, Infiltration/Inflow Studies, Lake and Wetland Analyses, Landfill/Hazardous Site Analyses, Pump Tests, River Gauging, Surface Water Monitoring, Sewer Flow Monitoring, Stormwater Studies, Weirs and Flumes, tide gauge measurements, and MUCH MORE...

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Options and Price List

WL15 Water Level Logger
Allows Logger to sit inside 2" well with enclosure rim on well casing top. Standard or locking well cap would completely hide the logger. Includes Windows-based Global Water Software. Specify Water Level Range: 0-3', 15', 30', 60', 120', 250'. Includes 25' cable.....$795
(Specify range upon order placement)

WLEXC Extra Cable
Cable length is measured from top of logger to bottom of sensor.
After 25', up to 500'.....$1.30/ft
(Specify total cable length upon order placement)

Locking Well Cap Fits over a 2" pipe $15

Deluxe Palm Package Handheld download package for WL15.....additional $200

Flume and Weir Option
Water Level Logger is 3' in overall length with a 3' range submersible sensor attached. Perfect for fitting inside a 1" PVC pipe for measuring flows in flumes and weirs. .....No Extra Charge

INO Inside Well Option
Entire logger goes down inside the 2" well. Provided with chain and hook to secure the well top. .....additional $40

PRP Pressure Pipe Option
Sensor is housed in a 6" stainless steel pipe with 3/4" NPT male thread for logging pressure in municipal water systems. 10' cable standard. Calibrated in psi with ranges of 30 psi, 60 psi, 100 psi available.....additional $35

SWO Sewer Flow Option
Mouse-shaped cover protects sensor from fouling and velocity effects in sewer, stormwater and irrigation pipe flows. Mouse is attached to 6" X 2' stainless steel strap for mounting sensor on pipe bottom.....additional $60

WL15 rentals are available.....$50/day*, $220/week, $700/month
(Call for available ranges and cable lengths.)

Top of Page

RainWise Inc.

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Rainwise.com Rain Gauge

Industrial Systems Rain Gauges Support Download Weather Home

The RAINEW WIRELESS Tipping Bucket Rain Gauge

RainWise, the world leader in tipping bucket rain gauges is proud to present the RAINEW WIRELESS rain gauge! That's right, no wires. Just mount this gauge, up to 300 feet away and read the rainfall amounts inside your house. This gauge design eliminates the normal wire connection from the rain gauge to the indoor display. The battery operated transmitter operates up to 300 feet away. Just locate the gauge in an open area and read the rainfall amount on the indoor display. The 8" diameter collector meets NWS specifications for statistical accuracy. Every time the bucket tips, a count is transmitted to the indoor display and the gauge empties. You never have to empty the gauge. Each tip of the bucket shows one hundredth of an inch on the indoor display.

In the Dual Counter display, the Current counter records rainfall in hundredths of an inch with a capacity of 9.99 inches. After the rainfall has ended, it may be reset to zero.

The Accumulation counter records the rainfall in tenths of an inch with a capacity of 99.9 inches. It has a separate reset.

This allows the user to determine the amount of individual rainfall events and also provide a total for a selected period of time.

The RAINEW WIRELESS rain gauge requires two "AA" batteries for the Transmitter, 3 "D" cells and a lithium button battery (included) for the LCD receiver/display. This FCC approved system has provision for 4 different codes so that any interference with another frequency can be eliminated. The RAINEW collector has a lifetime guarantee. The transmitter/receiver is guaranteed for a year. Both recorders have a keyhole slot in the back for wall mounting.

Rainew wireless rain gauge with dual display $199.95 Add to Your SHOPPING CART

Dual counter display for wireless rain gauge $99.95 Add to Your SHOPPING CART

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[Wired Gauges]

Made in the USA

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RainWise Inc.
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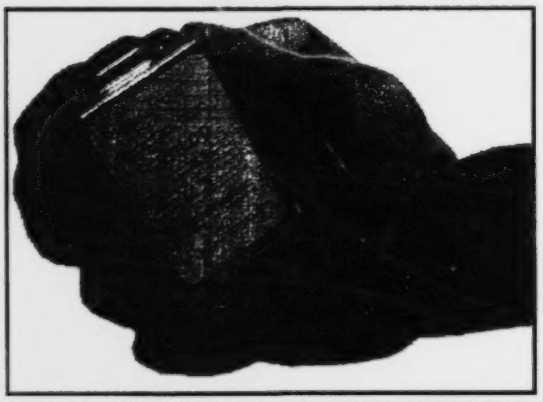
Rain Gauge
Rain Gauges Support Download Weather Home

RainLog - Rainfall data logger.

The RainWise RainLog datalogger provides an economical method of logging rainfall at a remote location where power is not available. This battery operated logger fits inside any of our rain gauges and will log total rainfall at a one minute resolution anywhere in the world for one year. It can easily be unplugged and connected to the serial port of a computer. It comes complete with Windows® software and serial port connecting cable.

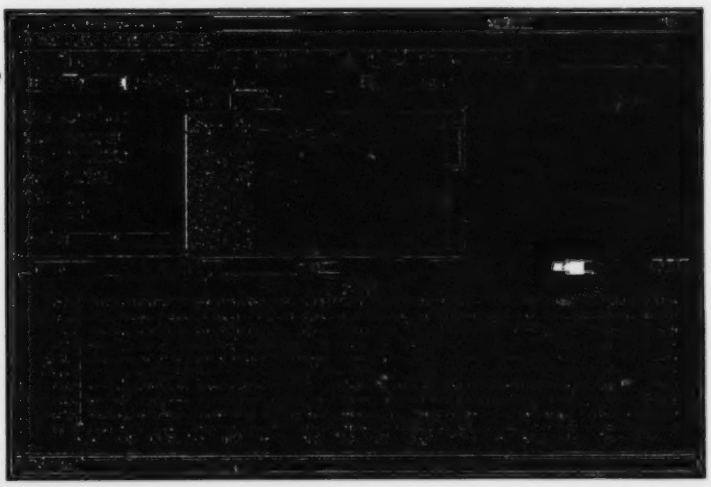


- One year capacity – both logger and battery supply.
- One minute time/date stamp resolution.
- Will fit inside any RainWise gauge.
- Nonvolatile memory.
- Powered by two AAA alkaline batteries.
- Windows® software included.
- **Price - $120**

RL-Loader 2 - Software

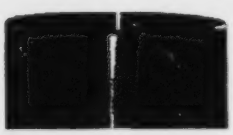
This free Windows based software package will run on Windows/95/98/ME/2000 computers with at least one free serial port. RL-Loader is used to configure and download data from the Rainlog. Data is displayed in both text and graphical formats. You can print graphs and reports directly. Previously saved data can be loaded to perform analysis and generate reports. The Device info window gives you vital information about the attached Rainlog like its time/date and the amount of memory used. The text window displays daily totals or the list of rainfall events as they occurred. The graph window displays a bar chart of the daily rainfall totals. The graphing range is also configurable. RL-Loader can also import files from RetrieverRL a Palm™ based software package for reading data from RainLogs.

Price - Free

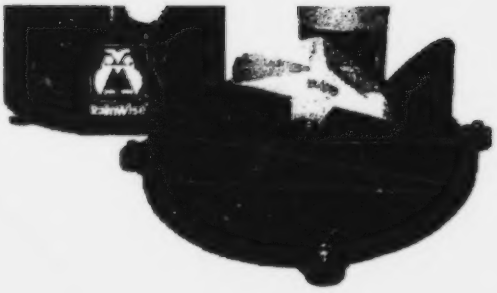


RainLogger - Data Logger and Collector

The RainLogger is a complete package containing a RainLog data logger, RL-Loader 2 software and polypropylene rain collector and mounting mast. The tipping bucket rain gauge is calibrated to 0.01 inches / 0.25 mm per tip.



Other calibrations are available on request.
Price - $295



Ordering

RainLogger- Data logger, software mounting post and rain gauge. **$295**

Add to Your SHOPPING CART

RainLog- Data logger and software (no rain gauge) **$120**

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Appendix IV

Geomembranes – Enviro Liner

LAYFIELD

Geomembranes - Enviro Liner

Enviro Liner® is our premium quality geomembrane material designed for top performance in all geomembrane applications.

Enviro Liner® is a proprietary polyolefin material designed for outstanding durability, chemical resistance, and flexibility. Enviro Liner® is manufactured by Layfield to stringent standards for all geomembrane applications. Whether you require manufactured roll stock, fabricated geomembrane panels, or complete installation services, Layfield's Enviro Liner® is your first choice in geomembrane technology.

Enviro Liner® is ideal for applications such as water and waste water, secondary containment and soil remediation, and pond and canal liners. Enviro Liner® has be specially formulated for long term UV durability. Enviro Liner® contains special additives to optimize UV life expectancy. Often a EL 30 or EL 40 Enviro Liner® can be used in place of thicker, more expensive geomembrane materials.

The flexibility of Enviro Liner® allows us to prefabricate large panels of liner in our plant. Often, entire ponds can be lined in one piece, speeding construction and minimizing field work. Enviro Liner® is ideally suited to cold temperature installations and is flexible in temperatures that would damage other lining materials.

Enviro Liner® has excellent chemical resistance and can be used for secondary containment in a variety of applications. Enviro Liner® is also used in water containment, canal, and most other liner applications.

4 Feb 2003	Enviro Liner® Minimum Material Properties			
Style	**ASTM**	**Enviro Liner® 20 (U)**	**Enviro Liner® 30 (U)**	**Enviro Liner® 40 (U)**
Thickness (Nominal)	D5199	20 mil 0.5 mm	30 mil 0.75 mm	40 mil 1.0 mm
Tensile Strength at Break	D638	77 ppi 13.5 N/mm	115 ppi 20.1 N/mm	152 ppi 26 N/mm
Elongation	D638	800%	800%	800%
Tear Resistance	D1004	11 lbs 49 N	16 lbs 71 N	22 lbs 98 N
Low Temperature Impact Resistance	D1790	-69°F -56°C	-69°F -56°C	-69°F -56°C
Dimensional Stability	D1204 Max Chng	1.5%	1.5%	1.5%
Puncture Resistance	D4833	28 lbs 125 N	42 lbs 186 N	56 lbs 250 N

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3 Sept 2002	Enviro Liner® Minimum Shop Seam Strengths			
Style	**ASTM**	**Enviro Liner® 20 (U)**	**Enviro Liner® 30 (U)**	**Enviro Liner® 40 (U)**
Heat Bonded Seam Strength	D6392 25.4 mm (1") Strip	37 ppi 6.5 N/mm	50 ppi 8.8 N/mm	70 ppi 12.2 N/mm
Heat Bonded Peel Adhesion Strength	D6392 25.4 mm (1") Strip	FTB 30 ppi 5.3 N/mm	FTB 45 ppi 7.9 N/mm	FTB 60 ppi 10.5 N/mm

3 Sept 2002	Enviro Liner® Minimum Field Seam Strengths			
Style	**ASTM**	**Enviro Liner® 20 (U)**	**Enviro Liner® 30 (U)**	**Enviro Liner® 40 (U)**
Heat Bonded Seam Strength	D6392 25.4 mm (1") Strip	30 ppi 5.3 N/mm	45 ppi 7.9 N/mm	60 ppi 10.5 N/mm
Heat Bonded Peel Adhesion Strength	D6392 25.4 mm (1") Strip	FTB 26 ppi 4.6 N/mm	FTB 40 ppi 7.0 N/mm	FTB 53 ppi 9.3 N/mm

Each and every liner panel we produce is a custom panel. The way we set up our shop is unique in that our shop welders produce prefabricated panels to best match your containment area. We size each panel to fit, without waste , in a logical sequence in your containment area. In containments with irregular shapes we size our panels to best accommodate the irregular size.

There are no theoretical limits to the size of the liner panels that we can prefabricate but there are some practical limits, notably panel weight. Panel weight is important because of the limits of handling equipment that will be vailable in the field. Enviro Liner® is normally limited to a maximum panel weight of 2,500 lbs (1,200 kg); however, if a skilled installation crew is available then a panel of up to 4,000 lbs (1,800 kg) is possible.

Enviro Liner® FABRICATION SIZES		
Material Style	**2500 lb Panel size 1120 kg**	**4000 lb Panel size 1800 kg**
Enviro Liner® 20 mil (0.50 mm) Unsupported	25,000 ft^2 2,300 m^2	40,000 ft^2 3,700 m^2
Enviro Liner® 30 mil (0.75 mm) Unsupported	17,000 ft^2 1,600 m^2	27,000 ft^2 2,500 m^2
Enviro Liner® 40 mil (1.0 mm) Unsupported	12,500 ft^2 1,200 m^2	20,000 ft^2 1,900 m^2

Panels are accordion folded in one direction and then rolled in the other direction. Unfolding instructions and dimensions are marked on the individual liner panel. Each panel is wrapped in an opaque, weather resistant covering suitable for shipment and storage.

All shop fabricated seams are 100% visually inspected by the welding operator. Every fifth seam is tested for Film Tear Bond and destructively tested in peel and shear. Quality control reports are prepared with each

Appendix V

Signs

Precipitation Harvesting for Livestock Watering

The objectives of this three year project are:

- To obtain a high quality source of water for up to 40 cow/calf units in a pasture area.
- To obtain the water reliably by gathering snow run-off and rainwater into cells by way of a membrane covered drainage area.
- To demonstrate the benefits and economics of two construction methods for improved precipitation collection.

Supported By:

Canada

Agriculture and Agri-Food Canada

Agriculture et Agroalimentaire Canada

CARDS

Saskatchewan Agriculture, Food and Rural Revitalization

ADF Agriculture Development Fund

PAMI

Western Beef Development Centre

Precipitation Harvesting for Livestock Watering

Project Site: 400 metres

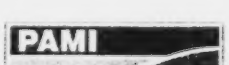
Supported By:

Canada Agriculture and Agri-Food Canada

Agriculture et Agroalimentaire Canada

Saskatchewan Agriculture, Food and Rural Revitalization

ADF Agriculture Developme Fund



Western Beef Development Centre

Appendix VI

Small System Excavation and Liner Costs

Small system surface area is 37% of the surface area of the large system

Small System Liner Costs

Enviro Liner for Holding Cell		
21.3 m x 21 m = 70 ft^2 x 69 ft^2 = 4,830 ft^2		
4,830 ft^2 x \$0.029877/ft^2 =	\$ 1,443.00	
Enviro Liner for Collection area		
30.48 m x 30 m = 100 ft x 98.4 ft = 9,840 ft^2		
9,840 ft^2 x 0.29877/ft^2 =	\$ 2,940.00	
Seam Tape (20% of Total Tape Costs) \$2,024 x 20% =	\$ 405.00	
Total Cost of Liner and Tape		**\$ 4,788.00**
Cost/ft^2 of Liner and Tape = \$4,788/9,820 ft^2		**\$ 0.50/ft^2**

Cost of Site Grading and Excavation

1/3 of total excavation costs = \$4,020 x 33% =	\$ 1,327.00
Total Cost of Liner, Tape, and Excavation	**\$ 6,115.00**
	========
Cost/ft^2 of System including Holding Cell Surface Area = \$6,115/9,820ft^2*	**\$0.627/ft^2**

* Surface area of collection area and holding cell.

Appendix VII

Large System Excavation and Liner Costs

Large system surface area is 2.7 times larger than the small system.

Large System Liner Costs

Enviro Liner for Holding Cell 38.1 m x 23 m = 125 ft^2 x 75.4 ft^2 = 9,425 ft^2 9,425 ft^2 x \$0.29877/ft^2 =	\$ 2,816.00	
Silver Liner for Collection Area 50 m x 100 m = 5,000 ft^2 x \$0.18/ft^2 =	\$ 900.00	
6 mil poly 4 rolls of 50 ft x 100 ft = 20,000 ft^2 x \$0.0408/ft^2 =	\$ 816.00	
Seam Tape (80% of total tape costs) \$2,024 x 80% =	\$ 1,619.00	
Total Cost of Liner and Tape		**\$ 6,151.00**
Cost/ft^2 of Liner and Tape = \$6,151/26,021 ft^2		**\$ 0.24/ft^2**

Cost of Site Grading and Excavation

2/3 of total excavation costs \$4020 x 66% =		\$ 2,653.00
Total Cost of Liner, Tape, and Excavation		**\$ 8,804.00**

Cost/ft^2 of System including Holding Cell Surface Area = \$8,804/26,021 ft^{2*} = \$ 0.34/ft^2

* Surface area of collection area and holding cell.